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THE

AMERICAN NATURALIST

VOL. XXXIII. *March, 1899.* No. 387.

THE PRESENT STATUS OF ANATOMY.[1]

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IT is a prevalent belief among the laity that anatomy is a practically completed study, that there is little or nothing to be added to our knowledge of the structure of the human body ; and for such a belief there is a certain amount of excuse. The human body has been an object of anatomical study and investigation for centuries ; hundreds of volumes, ranging from duodecimos to folios, have been written about its structure; thousands on thousands of bodies have been dissected ; and why, then, are we not in possession of a full knowledge of the subject ?

Such reasoning overlooks the fact that in every science there is not one but two elements, the material and the intellectual, which react upon one another, new observations producing new generalizations, and these again pointing the way to new fields for observation. But the misconception as to the present status of anatomy depends upon a misconception of a more fundamental idea, *i.e.*, of what is meant by science. To the popular mind science is merely the collecting of natural facts. The scientist is pictured as an inquiring Gradgrind, who seeks for facts, facts, and nothing but facts ; he weighs, he measures, and he describes; and weighing, measuring, and describing constitute science. No ! The collection of facts, no matter how accurately accomplished, is no more science than the alphabet is literature. As Huxley has well put it, "the mere accumulation of facts without generalization and classification is as great an error intellectually as, hygienically, would be the attempt to strengthen by accumulating nourishment without due attention to the primal *viæ,* the result in each case being chiefly giddiness and confusion in the head." Observation alone is not science ; facts without deduction are merely the clay without the straw. Observations, accurate and extensive, are a primal necessity, but observation alone merely furnishes the crude material from which, by reflection and deduction, scientific facts may be obtained.

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[1] An address before the Catholepistemiad Club of the University of Michigan, Dec. 16, 1898.

So then, what is usually regarded as the whole of anatomy — descriptive anatomy — is not necessarily a science ; it constitutes merely an aggregate of facts upon which deduction may act, and it is the sum-total of the observations and deductions that constitutes the science.

The purpose of this address is to consider chiefly the general standpoint of anatomy as it is at present, but a few words seem necessary concerning the more observational side. The facts or observations at the disposal of the anatomist of to-day are enormously more numerous and detailed than those available at, let us say, the beginning of the present century ; and this progress along the material side has been largely due to the greater facilities for observation which we now possess. The anatomists of the sixteenth and early part of the seventeenth century possessed only such information as was afforded by the use of the scalpel and their unaided vision. In the seventeenth century a new tool was placed in their hands, the microscope, without which the anatomist of to-day is well-nigh helpless. At once new fields for observation were revealed and many new facts were secured, though for many years the microscope was rather a plaything than a tool. Indeed, it was not until the present century was well advanced that the optical imperfections of the compound microscope were overcome and the instrument we now so constantly employ was within reach.

But, after all, the microscope, *per se*, in anatomy has enormous limitations. A fragment of tissue taken from the body and placed at once beneath the strongest powers of the microscope yields but few of its secrets. The great development in the modern use of the microscope, if I may so express myself, has been in the methods of preparation of the tissues to be examined, methods which have become so familiar to workers with the microscope that they are apt to forget how very recent they are. The hardening of tissues was not introduced until the beginning of the present century (Reil), and then alcohol alone was used; the processes of "fixation" previous to hardening had their origin in the discovery of the value of osmic acid for this purpose by Max Schultze in 1864; section cutting, even free-hand, was not generally employed until after the middle of the present century; staining was first employed by Gerlach in 1858; and mounting in refractive media was introduced by Stilling about the same time as section cutting (1840).

How rapid, then, has been the development of our modern methods! To-day instead of one "fixative" we have our choice of many; instead of cutting our sections with the free-hand and spoiling many, we have instruments of precision by which we can cut an entire organism or a piece of tissue into sections $\frac{1}{2500}$ of an inch in thickness without spoiling one, and, if necessary, can obtain sections of $\frac{1}{10000}$ or even $\frac{1}{25000}$ of an inch, so perfect have our methods become. While Gerlach knew only one medium for staining, namely, carmine, to-day we have dozens, the discovery of the anilines placing in our hands a marvelous aid to microscopical investigation. By their use we can differentiate tissues. One dye will have an affinity for nerve tissue, another for yellow elastic tissue, another for mucin; others will affect most strongly the chromatin of the cell nucleus, others the cell body or cytoplasm, and so on; and thus, by choosing the proper method, it is possible to differentiate structures in a most marvelous manner.

So then the anatomist of to-day, by the proper employment of the methods at his disposal, has it in his power to make observations undreamt of, in their minuteness, by the masters of fifty years ago, and wonderfully more perfect than those possible even fifteen years ago. How then, even from the observational side, can anatomy be a completed science?

But now, leaving this side of the story, let us examine the difference between the higher intellectual side of anatomy as it is to-day and what it was in the past.

It is interesting to note the impartiality of the intellectual stagnation of the Middle Ages. The neglect of Aristotle, so marked in philosophy, is paralleled by a similar neglect in the department of Natural History; Pliny, with his fabulous tales and uncritical compilations, being the great authority. In anatomy the condition was largely the same. Original observation was almost neglected, utmost reliance being placed upon the *dicta* of Galen and any attempt to criticise his statements regarded as a heresy. When, accordingly, Vesalius, in the first half of the sixteenth century, disregarding the dictates of antiquity and entering upon a course of investigation for himself, pointed out that the facts which Galen set forth as applicable to the human body, and which were in reality founded largely upon observations made chiefly in dogs and monkeys, were in many particulars erroneous, he encountered a storm of derision and obloquy. The correctness of his observations had to be recognized however, though with great unwillingness; but even then his opponents, notably his former teacher, Sylvius, maintained the correctness of Galen's descriptions and endeavored to explain away discrepancies by asserting that the structure of the human body must have changed since Galen's time. Vesalius had pointed out that the bones of the leg are not curved, as Galen had asserted. "Granted," cried his opponents, "but they were curved in Galen's time, and their straightness now is due to the substitution of close-fitting garments for the flowing robes of earlier times."

On the death of Vesalius in 1564, the influence of his opponents produced a revival of Galenism, but the leaven had begun to work and the zeal of Vesalius had marked an epoch in anatomy. Careful observation and description became more and more the order of the day, and led in 1619 to the discovery by Harvey of the circulation of the blood, a discovery which marked a second great epoch in the history of anatomy. It laid the axe at the root of the spiritual theories prevalent at the time, which recognized as the essence of life an unknown something, the *spiritus* or *aura*, which, being confected in the liver, served to distend the heart, whence it was distributed as a *spiritus naturalis* by the veins to certain organs of the body, and as a *spiritus vitalis* to others by the arteries. Harvey's discovery necessarily proved a serious blow to such vague ideas, though in one form or another they continued to exist for nearly two centuries, the *spiritus* being a ghost difficult to lay. Harvey showed that the heart was not passive, but was a muscular pump, that the heart and not the liver was the starting point of the circulation, that the blood of the arteries and of the veins was the same, and that the course of the blood in both sets of vessels was in a definite direction. And by so showing he laid the foundation stone of our modern science of physiology.

But the seventeenth century is entitled to the credit of laying the foundation stone not only of physiology, but also of microscopical anatomy and of comparative anatomy. Leeuwenhoek, polishing his own lenses and subjecting to their action whatever came to his hand, made many important discoveries, chief among which appear bacteria, the yeast plant, and spermatozoa; and Malpighi discovered the blood corpuscles and completed the missing link in Harvey's scheme of the circulation by describing the capillaries by which the veins and arteries are placed in communication.

The interest awakened in human anatomy in the sixteenth century was not accompanied by an equal interest in the study of the lower forms, but towards the close of the seventeenth century comparative anatomy was again called to the aid of human anatomy by Nehemiah Grew, by Tyson, who availed himself of an opportunity for dissecting an ourang and carefully compared its structure with that of man, and by Collins, who with Tyson's aid illustrated the structure of the human body by references to the peculiarities of structure found in the lower animals.

And, finally, as a crowning glory of the seventeenth century, we must not forget the inauguration in it of the science of embryology, with which the name of Harvey must also be associated, his predecessor in the study being his teacher, Fabricius ab Aquapendente.

But it is merely the beginnings of these various adjuncts to anatomy that we find at this period. At this time, and indeed until much later, anatomy was regarded simply as a medical study, and investigation in it was conducted for a distinctly practical end. On account of its relations to medicine it came under the influence of the medical theories which prevailed at the time, and these theories, frequently changing, at one time stimulated observation and at another retarded it. Anatomy, instead of flourishing under a theory of its own, was overshadowed by, or received but reflected lustre from medical theories, and it is of interest on this account to consider these latter briefly.

If I were asked to characterize in a few words these theories, I would say that they belong to two distinct classes, those of the one class being based upon a dualistic conception of the structure of the body, while those of the other might be termed monistic. Those of the one class seem to have served as stimuli to those of the other, and the history of the theory of medicine from the sixteenth to the beginning of the nineteenth century has been a history of an almost regular alternation of dualistic and monistic hypotheses. As pertaining to the dualistic group, the sixteenth century doctrines of Paracelsus may be mentioned, according to which the physiological and pathological processes of the body were the result of a controlling spirit, termed the *Archeus*, and this view was also maintained with slight modifications by Van Helmont in the beginning of the seventeenth century, he, too, recognizing a dominant Archeus to whom were subordinate other *Archei insiti*, disease being due to "the passions and perturbations of the Archeus," and the treatment of the physician an attempt to modify the ideas or emotions of this *ens*.

Naturally there was ere long a reaction from such a fantastic hypothesis, and we find in the seventeenth century two monistic schools, the Iatro-chemical and the Iatro-physical, which, as their names indicate, regarded the physiological processes of the body as chemical or physical in their nature. These theories were, however, too advanced for the times, and even Sylvius, the chief exponent of the chemical school, while regarding many diseases as the result of disturbances of the chemical processes of the body, still held to the idea of a *spiritus* when it was a question of nervous disturbances.

Later, at the beginning of the eighteenth century, Boerhaave emphasized the monistic views, and to a certain extent combined the principles of the two schools just mentioned by finding the causes of disease in the degree of cohesion of the particles composing the elementary fibres of the body and determining their strength or feebleness, their laxity or tenseness, and in the chemical and physical characters of the body fluids, their acidity, alkalinity, or viscosity. And almost at the same time we find a revival of the dualistic idea in the animism of Stahl, who revived to a certain extent the Archeus of Paracelsus under the name of the "anima" as the controlling element of the physiological processes of the body.

But it would take too long to even merely touch upon the numerous theories which marked the eighteenth century as the age of systems. The desire then prevalent of establishing a general principle which would govern the practice of medicine seems to stand in close relation to the tendency to establish systems which became evident in the philosophy of the times, and, if time permitted, it would be interesting to consider the influence of such minds as Descartes and Leibnitz on the medical theories of their day.

To a certain extent these various and vacillating theories retarded the progress of anatomy and physiology, but not entirely so. For a theory is merely a working hypothesis, an index of the lines along which further observation should proceed, and so, even though it may be fundamentally erroneous, it need not necessarily obscure for long the progress of thought, the observation which it stimulates soon correcting it and substituting for it more accurate ideas. The search for the elixir of life yielded many valuable results to chemistry; for, as Cowley has expressed it:

> So though the Chymist his great secret miss
> (For neither it in art or nature is);
> Yet things well worth his toil he gains,
> And does his charge and labour pay
> With good unsought experiments by the way.

And so, though under the influence of erroneous theories and in an attempt to elucidate by commentaries the physiological ideas of Boerhaave, Haller, between 1746 and 1765, added greatly to the knowledge of anatomy and placed another stone on the foundation of modern physiology by the discovery of the contractility of muscle and the irritability of nerve.

The close of the century, or, rather, the beginning of the nineteenth, was marked by the appearance of a work of far different calibre than the majority. I mean the *Anatomie générale* of Bichat, published in Paris in 1801. Bichat combines, to a certain extent, the monistic tendencies of Boerhaave with the animistic ideas of Stahl, but, making use of Haller's discovery and by adding much of his own, he evolves a much more scientific and progressive system. He recognizes Stahl's animism as a pure abstraction and supplants it with two physiological processes, the irritability and contractility of Haller, which, he claims, are properties of all organs of the body and not of nerve and muscle alone. Digestion, circulation, secretion, in fact all the functions, are performed by the interaction of these two processes. So far this is an improvement in Stahl's ideas, but the great importance of Bichat's theories rests in that he makes these vital processes reside in the solids of the body. They are not absolute entities controlling the functions of the body, but in a sense they are these functions, and since disease is a disturbance of the functions, a modification of the vital processes, it is dependent upon a modification of the solids or tissues of the body.

Such a theory necessarily led to a more minute and careful study of the finer anatomy of the organs of the body, both in health and disease, and indeed was the result of such studies carried out largely by Bichat himself. That the body was composed of numerous organs was clearly understood, but Bichat pointed out that the structure and function of an organ is dependent upon components, the tissues, which enter into its formation. To quote his own words: "Every animal is an assemblage of different organs, which, each performing a single function, subserve, each in its own way, the preservation of all. They are so many special structures in the general structure which constitutes the individual. Now these special structures are themselves formed of several tissues of very different natures, and which, indeed, form the elements of these organs. Chemistry has its simple bodies, which form, by the various combinations of which they are capable, compound bodies; such simple bodies are heat, light, hydrogen, oxygen, carbon, nitrogen, phosphorus, etc. Similarly, anatomy has its simple tissues, which, by their combinations in fours, sixes, eights, etc., form the organs." Elements of lower grade than the organs had been postulated in earlier times; thus Boerhaave speaks of elementary fibres which form certain structures and Asclepiades, still earlier, applied to anatomy the Epicurean doctrine of atoms. But one of these was a philosophical abstraction and not a scientific hypothesis, and the other a crude generalization not applicable to all parts of the body. Bichat's tissue element is, however, accepted to-day as an individual of simpler grade than the organ individual, and though we do not recognize as perfect his definition of tissues or his enumeration of them, yet the ground idea is the same, except in so far as it is influenced by the cell theory of a later date.

If, now, the epoch-making discoveries in the history of anatomy in the sixteenth, seventeenth, and eighteenth centuries were to be summed up briefly, there would be placed first and foremost the overthrow of the Galenian traditions, and the revival of observation by Vesalius (1516–34); next the discovery of the circulation of the blood by Harvey (1619); next Haller's discovery of the irritability and contractility of nerve and muscle (1746), and, finally, the formulation by Bichat of his tissue elements and the overthrow of both the ultra-physical and the ultra-animistic theories of disease (1801).

During all the period hitherto considered anatomy remained very largely in the observational stage, and was ancillary to medicine. In the mean time, however, investigations were proceeding in allied branches of biological science, which were destined eventually to place anatomy in the category of the sciences.

In Germany, Johannes Müller and Meckel; in England, Hunter, Home and, later, Owen; and in France, Vicq d'Azyr, Étienne, and Isidore Geoffroi St. Hilaire, Lamarck and, especially, Cuvier, prosecuted with vigor and enthusiasm the study of comparative anatomy, the results of their observations calling into existence two diametrically opposed deductions, on the one hand the doctrine of Types espoused by Cuvier, and on the other that of Transformationism, upheld by Étienne Geoffroi St. Hilaire and Lamarck. Cuvier's theory, briefly stated, was that in the animal world there was a definite number of structural types or plans, to one or other of which every animal could be referred. The theological bias of the theory was strong; the plans or types, having existed in the mind of the Creator from the beginning, were fixed and immutable; connecting links between them were impossible; they were circles whose boundaries might touch but could never overlap. And, furthermore, the theory involved the idea of a special creation for each species, the species being consequently as immutable as the types. Man, therefore, was structurally isolated, and the similarities known to exist between him and lower forms could have no significance.

To Lamarck and St. Hilaire the facts of comparative anatomy pointed to entirely different conclusions. To them there was a fundamental unity in the animal kingdom; as some one has said, they took a synthetic, and Cuvier an analytic, view of nature. This unity was possible only by an absence of a fixity of type, by a mutability of species, and these were the ideas they opposed to Cuvier's scheme of creation, the ideas of transformationism or evolution practically as we now understand it.

The controversy between the two schools was prolonged and bitter, and culminated in the celebrated passage of arms before the Academy of Sciences in Paris, which, to Goethe, seemed more important than the victories of Napoleon. The enormous authority of Cuvier and the theological bias of his theory gained the day, however; the doctrine of transformationism retired temporarily from the field, and anatomy retained its isolated position.

Attention has already been called to the inauguration of the science of embryology by Fabricius and his pupil Harvey. During succeeding years it languished somewhat, but was finally established as an important branch of biology in the present century by the publication of the *Beobachtungen und Reflexionen* of von Baer in 1829. A masterly study of the development of a number of vertebrate organisms led von Baer to formulate a principle of developmental unity by his doctrine of the germ layers, and also to establish an idea of transformationism for the individual by demonstrating that in its development the organism proceeds from a more generalized to a more specialized condition; that is to say, it presents first what for convenience may be termed type characteristics, later the family, then the generic, and then the specific peculiarities being added or superimposed.

About the same time important ideas were working out in another department — that established by Malpighi and Leeuwenhoek — microscopical anatomy. Improvement of the microscope made possible the discovery in 1838 by the botanist Schleiden of cells as the ultimate structural units of plants — a discovery completed in the following year by Schwann, who extended the generalization to animals, and at the same time materially modified the meaning attached to the word *cell*. These discoveries were the following out of the idea of analysis suggested by Bichat, and were indeed the analysis of his tissue elements into individuals of a still lower grade. A further step was, however, still necessary to convert the cell-theory of structure into its modern form, and that was the formulation of the protoplasmic theory by Max Schulze in 1861. Just as cells had been known long before the cell theory was postulated, so, too, protoplasm had been known ever since the amœba was first observed by Rösel von Rosenhof in 1755. The attention to the nature of the cell contents, awakened by the cell theory, led the botanist von Mohl to recognize in vegetable cells a viscous material distinct from the cell sap, to which he gave the name protoplasm. This was in 1846, but even before this Dujardin, in 1835, had described what he termed the *sarcode* in the Foraminifera. Schulze much later identified these two substances and modified the original cell theory by making a mass of protoplasm, independent of any special bounding wall, such as the word *cell* implies, the unit of structure. He converted Bichat's tissue elements into aggregates of protoplasmic elements, and, by extending his generalization to plants, made possible Huxley's characterization of protoplasm as the "physical basis of life."

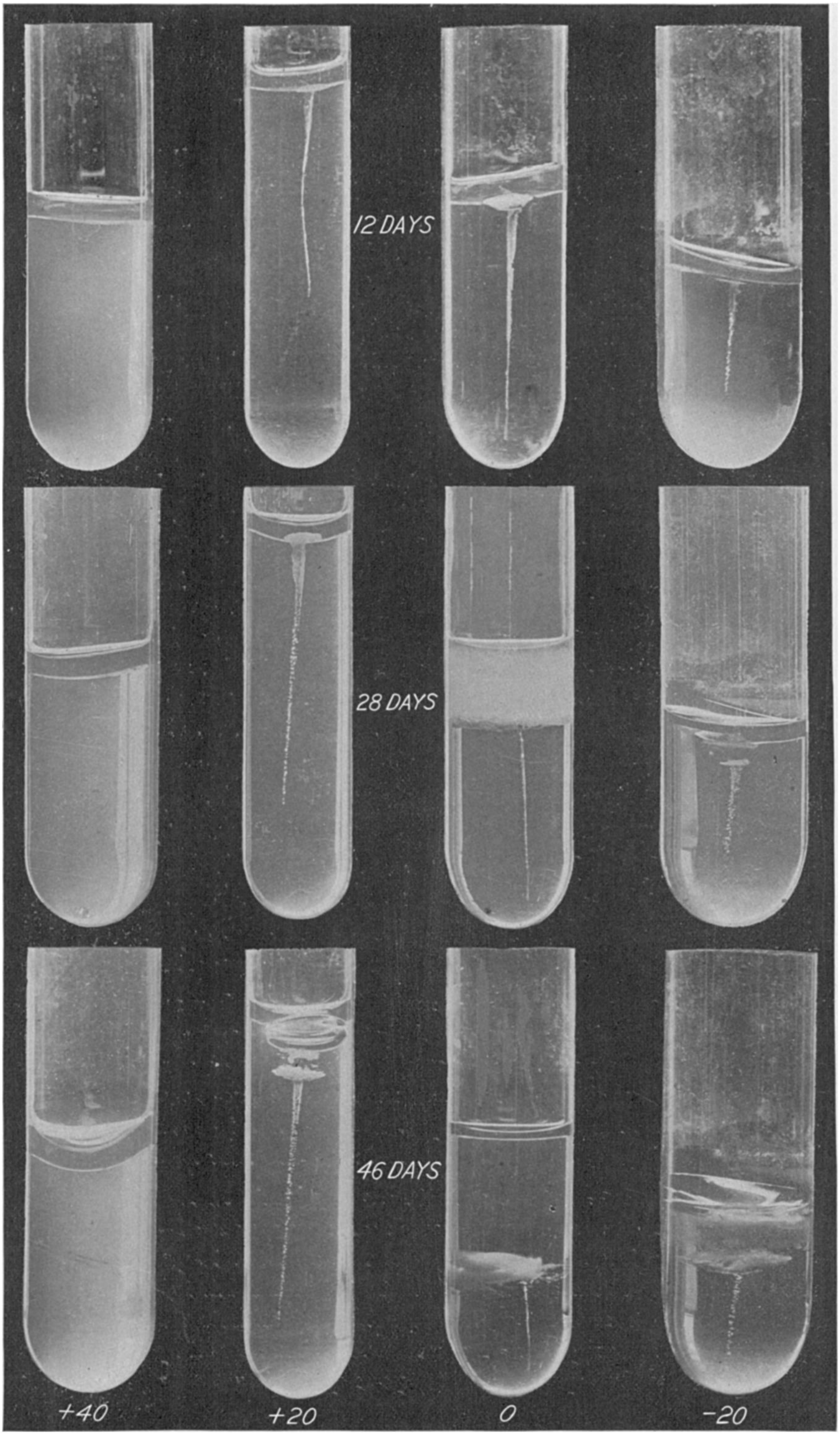
All these discoveries and hypotheses were contributing to prepare the mind of the scientific world for the reawakening of the doctrine of evolution. The theological bias and the influence of Cuvier were still powerful at the middle of the century, but they could not withstand the march of observation and deduction which was tending surely to the overthrow of the Type theory, a result accomplished by the publication of Darwin's *Origin of Species* in 1859. Darwin's generalizations and the resulting acceptance of the theory of evolution at once placed anatomy in a new position. It could no longer be held aloof from the other biological sciences. Man is not an organism entirely distinct from all others; he is merely the culmination of one line of evolution. His structural peculiarities are not minute details of a primary immutable plan, but are to be explained by reference to his past history. Departures from the typical conditions, so frequent and in many cases so remarkable, are not mere vagaries without significance, but are reminiscences of previous conditions or indications of developmental possibilities frequently brought to completion in other forms.

The doctrine of evolution is the "one increasing purpose" whose influence is traceable throughout all science, and it has consequently broadened all our views by bringing the various departments of research into interdependence with one another. This is the age of specialties, and necessarily so, since the volume of knowledge has grown too great for one finite mind to comprehend the whole; but now, more than ever before, there is necessity for correlation. Each department of science no longer stands isolated; no longer can a thorough and extensive research in any specialty be conducted without reference to other specialties and other departments. And it is this which stands out so clearly in the science of anatomy as it is to-day. It is no longer an isolated study, but merely a part of a wider field of knowledge. In the past it was a land-locked sea, but the erosion of the smaller streams of discovery and, finally, the overwhelming flood of the evolution hypothesis swept away the barrier which separated it, and it is now a small bay of the great ocean of morphology. In the past anatomy was human anatomy; to-day it is synonymous with morphology. No longer do anatomists confine their attention to merely accurate descriptions of the details of the structure of the body; they seek to discover the significance of these details. Anatomy has become "denkende Anatomie," to use the expression of Johannes Müller; it is no longer tied to the apron-strings of its mother, Medicine, but, having come of age, has taken its place in the rank of the sciences, the *Origin of Species* and the *Descent of Man* having been its Declaration of Independence.

How, then, can our knowledge of the structure of the human body be complete? Modern anatomy is not yet fifty years of age, and this is infancy compared with the sister sciences. All that has been accomplished from the time of Aristotle to the middle of the present century was largely merely a preparation, and the time that has elapsed since then has been far too short for the solution of all the problems which confront us. Goethe has said of another department of study: "History must from time to time be rewritten, not because many new facts have been discovered, but because new aspects come into view, because the participant in the progress of an age is led to standpoints from which the past can be regarded and judged in a novel manner." So it is with anatomy; the new standpoint calls for a new interpretation of anatomical facts and a restatement of our knowledge of anatomy.

It seems unnecessary to run the risk of tediousness by enumerating the problems of anatomy of to-day, their number being endless. I trust I have made its present standpoint clear, so clear that he who will may read between the lines and see that an anatomist can do as much, indeed I would even say he can do more for the advancement of his science by prosecuting investigations in comparative anatomy and embryology than by confining his attention to man alone. Why should the anatomist, endeavoring to unravel the mystery of the structure of the most complicated organism known to him, waste his time and energy in studying that organism alone, when he can trace step by step the gradual increase of the complexity in the lower forms of life, and, by learning to understand the simpler conditions, place himself in a position to understand the final complexity?

More than one hundred years ago the Abbé Dicquemare wrote: "Everything that relates to animals, their manner of being, the growth and diminutions which they show, their generation, their strength, their actions, their diseases, their nourishment, the duration of their lives, the phenomena which they manifest even in death, all these are subjects which ought to interest man. If his moral being does not offer any analogy to theirs, his physical constitution permits comparisons." The new anatomy is interested in all these subjects; it is catholic in its extent. From amœba to man every organism falls within the jurisdiction of the anatomist, and there is no problem of morphology but is his for solution, no observation however insignificant but is his for application. "Neque enim ad agendum et potestatem sive operationem humanam amplificandam sufficit, aut magnopere attinet, nosse ex quibus res constent, si modus et vias mutationum et transformationum ignores." These words of Lord Bacon would well serve as a motto for the anatomy of to-day.



PSEUDOMONAS CAMPESTRIS.

Behavior in gelatin containing varying amounts of Sodium hydrate. (See Gelatin Culture Media, — 2d Ann. Meeting Soc. for Plant Morphology and Physiology.)